Mobile Health Solutions for Biomedical Applications

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Chapter XIII
Technology Enablers for Context-Aware Healthcare Applications

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ABSTRACT

The increasing availability of mobile devices and wireless networks, and the tendency for them to become ubiquitous in our dally lives, creates a favourable technological environment for the emergence of new, simple, and added-value applications for healthcare. This chapter focuses on how context and location can be used in innovative applications and how to use a set of solutions and technologies that enable the development of innovative context and location-aware solutions for healthcare area. It shows how a mobile phone can be used to compute the level of familiarity of the user with the surrounding environment and how the familiarity level can be used in a number of situations.

INTRODUCTION

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." (Weiser, 91)

In 1991, Mark Weiser had a vision that still inspires many researchers in the ubiquitous and pervasive computing area. In a perfect world people needs would be detected and fulfilled by a set of devices that would act in the background to provide the means or data necessary to the users' activities. Current technology does not allow to entirely fulfilling the Weiser vision but allows realizing many aspects of this pioneer vision.

Continuous monitoring of the health condition of people has been desired for many years, in particular for impaired persons or for people requiring special health treatments. In certain cases, these requirements for continuous monitoring force people to stay at the hospital facilities for a few days, such as when monitoring cerebral activity, or force them to visit the hospital every few days for downloading data from portable monitoring equipment to a server, such as when monitoring the hearth rate.

The increasing availability of mobile devices and wireless networks, and the tendency for them to become ubiquitous in our dally lives, creates a favourable technological environment for the emergence of new, simple, and added-value applications for healthcare.

One major opportunity resulting from this technological evolution is that electronic health assistants can now be used by everyone, independently of their health condition.

The technological evolution achieved during the lasts years lead to more sophisticated environments. We have more sophisticated users in the sense that more people use more technology in their living and have their lives controlled by technology, and also because more technological devices exist to assist people that search for healthcare services. WLAN, Bluetooth, mobile phones, digital diaries are among some of the most popular technologies used today by many people. Others technologies control peoples' life individually or collectively, many times without people noticing it, like remote video surveillance or remote traffic control systems.

To explore and take advantage of these new technologies it is necessary to solve a set of technical, ethical and legal problems. Pervasive and ubiquitous computing devices can be very useful to people, providing important information and establishing an infrastructure that enables the emergence of a new kind of applications and services: the context-aware services and applications.

In context-aware computing, applications adapt their behaviour accordingly to the context of its users. The context is all the information that characterizes the user in a specific moment. It may include the location, position, a list of nearby objects (e.g. people), the user's activity, the available resources, some user's vital signals, and even the familiarity of the user with his/hers surroundings.

Among the technical problems that need to be worked out are the notion of context and the context management. Until today, many location-based and context-aware services and applications were built based on specific solutions, where location or other data was directly used from the sensors.

Context management should be done through an open and generic entity capable of supporting virtually any sensor or positioning service, without imposing a specific space model and by being capable to support a context based on multiple dimensions.

Context is all the dimensions (all the information) that characterize a user in a specific moment. Some basic dimensions of a context may be obtained directly from physical sensors, while some others may be calculated from raw data or may even be estimated from the information provided by other dimensions.

Location and position have been the most used dimensions when creating context-aware applications and services because there are more sensors and services capable of provide this kind of data than any other dimension. Moreover, position and location are among the dimensions that, in fact, influences a lot the interaction of people with computing devices. Context-aware applications that rely primarily on location are known as location-aware. Location-aware applications provide to mobile users the possibility to access services and information that are relevant to the user in a specific moment and location.

A number of technologies can be used to acquire the user's position and location, inside and outside buildings. In the last decade, research in context and location-aware computing produced frameworks and solutions that enable the easy development of context-aware applications. In particular, several developments in context management frameworks provided the tools for programmers to access the context of users without the need to deal directly with the low-level technical details of the sensors used to acquire the context, and allowing the use of several technologies simultaneously to provide position and location with more precision and in more places. For example, the Place Lab system (LaMarca, 2005) exploits the beacons broadcasted by many wireless networks to estimate the geographic position of mobile users.

Many of these technologies enable the development of new solutions for healthcare, improving the cares with people in a hospital, for sick persons that are at home, for an accident victim, for the doctors and for those who rescue the victims of accidents. In this chapter we discuss how context and location can be used in innovative applications and how to use a set of solutions and technologies that enable the development of innovative context and location-aware solutions for the healthcare area.

This chapter is organized as follows: section 2 presents what is a user' context and how it should be managed. Section 3 presents some technologies that can be used to acquire some of the user' context dimensions. Section 4 shows how an ordinary mobile phone can be used to detect the user movement and the data collected by the phone can be used to create a personal space model and to infer the familiarity of the user with a place. The last section presents the conclusions of this chapter.

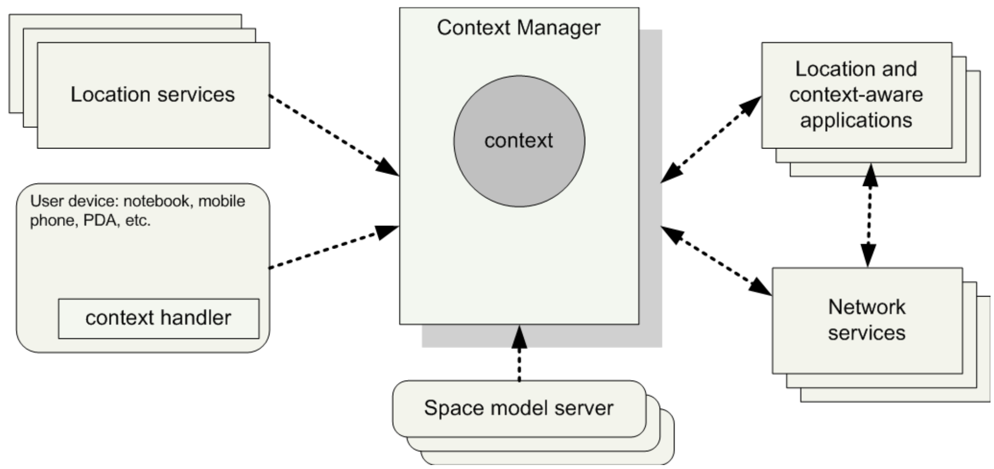
CONTEXT AND CONTEXT MANAGEMENT

Considering that a user' context is something very wide, that can contain a considerable and variable number of dimensions, we sustain that context should be represented by an unbound and dynamic list of attributes, represented by standardized and non-standardized data structures, with mandatory and optional attributes. Context is a cumulative storage of knowledge, being able to describe the current situation of a person and also remember past experiences.

Context management should be done by a pervasive universal service, capable of dealing with any number of context sources. In (Meneses, 2004) we proposed a generic context manager capable of receiving data from virtually any sensor or location service, that provides an interface that allow authorized client applications to access to user' context represented by a XML stream. The developed solution also allows some other functionalities like the use of space model servers to complete the context information and a publish-subscribe mechanism that allow applications to request to be notified by the context manager when the context (or a specific dimension of the context) changes. Figure 1 shows the context manager and the main entities that interact with it.

The context manager holds and manages the context object which contains the user' context. It receives contextual information from location services that can exist on the infrastructures (like, for example, a positioning mechanism on a wireless network or soft sensor that detects the presence of the user mobile phone nearby an Bluetooth access point) and from context handlers that run on a user device. An example of a simple context handler, to be run on the user device, is a software that detects and updates the context with the BSSID of the WiFi networks detected or a software that updates the context with the

Figure 1. The context manager that manages the context and interacts with a set of external entities



geographic coordinates that retrieves from a GPS receiver. Data received by the context manager is integrated into the user context becoming available to be used by applications and services that can run on the user device or in the network.

The context manager, besides integrating the data received from sensors, can also improve the user' context using some external services capable of providing additional information about the collected data, and can also execute inference algorithms that supply new contextual dimensions. For example, the context manager can execute an algorithm that by processing the GPS coordinates is able to automatically determine if the user is at home or at his/her workplace (Moreira, 2005). Other example is the possibility of using data available at GSM phones to automatically infer high level information about the current situation of a user.

AVAILABLE TECHNOLOGIES AND SOLUTIONS

Today, there are a wide number of technologies that can be used to acquire the user' location and position. Some of those technologies, like the Active Badge (Want, 1992) or Active Bat (Ward, 1997), were specifically developed to acquire the user' location or position inside buildings. Other technologies, like WiFi networks or Bluetooth access points, were initially developed for a different proposes but can also be used to locate a user.

The lack of a universal pervasive solution for location/position is one of the main problems that block the bootstrap of location-based services and applications. Even GPS receivers, that become popular in the last years, are not a universal solution because it only works in open areas and not everybody has a receiver.

What is necessary is a solution that can be deployed by anyone, everywhere, and pervasive enough to not interfere on people's life. Currently, the best possible solution is to use mobile phones. If we look to a person on the street, at home, at work, going out with friends, etc., we observe that a mobile phone is the technological device that is always present and always turned on. Unlike a laptop that only some people have and it is only turned on when it is needed, or a GPS receiver that people use mainly in car, mobile phones are almost universal (ubiquitous): almost everybody has one, it is kept turned on most of the time and the user takes it everywhere.

Several mechanisms were developed to acquire the mobile phones' position. Angle of Arrival (AOA), Time Difference-Of-Arrival (TDOA) and Enhanced-Observed Time Difference (EOTD) are some of the solutions developed to acquire the location of mobile devices in GSM cellular networks.

These technologies provide the positioning data of mobile phones to network operators which usually do not make this information accessible to applications running outside their backbones. Hopefully, there is a basic position mechanism, known as cell-ID positioning, that is done at the mobile terminal by identifying the network cell being used in that moment by the handset. The accuracy of cell-ID method is reduced when compared with the others mechanisms but has the advantage of being possible to be done on the user handset, without depending on any network service.

GSM networks are made of cells with each cell covering an area. In rural areas, with fewer users per square kilometre the cells are usually bigger, covering a wide area. In contrast, in urban areas cells are usually smaller. Each cell supports a limited number of users thus in urban areas the cells are usually smaller with more cells covering the same area in order to support the communications requirements of all the users.

Each cell has a numeric unique identifier, generically called cell-id. Mapping each cell-id into a geographic position would allow finding the location of the user in a well known referential. However, this mapping is a difficult task because network operators do not make their network configuration or base station positions public. Mapping each cell manually would be a big effort considering that new cells and changes in the network configuration would have to be detected in order to keep the service updated.

Medical equipment with network connectivity is also becoming available, enabling the development of integrated systems where the patient's data is available and monitored remotely. Moreover, automatic collection of data from medical devices allows more complete patient medical histories (with less mistakes introduced by manually collecting data and with more data – data collected more often). Reasoning algorithms that process this data can detect and foresee health problems based on the user history or simply remember or automatically instruct medical devices to apply certain drugs.

Users' history and scientific knowledge can be joined in data mining and machine learning algorithms to create knowledge and predict the user medical evolution.

Current technology allow to locate doctors inside an hospital, access patients records automatically when a doctors gets near a patient or to locate a patient that may suffer from memory problems and get lost on a street, etc. However, smarter applications can be developed.

Some health services and equipments already provide medical records in an electronic format. The next stage of the technological development should be the integration of the records into the user context. The integration would allow to simultaneous access to the medical records and to other dimensions of the user context which could benefit the user and medical staff. Information like the familiarity of the user with the surrounding environment or the user location can help medical rescue services. Information about the presence of familiars or friends nearby can provide valuable information that benefit the medical staff and also the patient, allowing to have information about what happened to the patient before the lost of conscience or to find out if any other person would be with the injured patient at the moment of a accident and it is still missing. Having a user' context that keeps memory of the user movements will help to know easily where the user was before and to find and contact the persons that were with the ill person.

IMPROVING CONTEXT WITH TODAY'S TECHNOLOGY

If a person is involved in a medical emergency situation, the attitude changes according to the place where the emergency occurs, whatever the person is the victim or the rescuer that provide assistance to injured persons. A certain health problem can be less critical if the person is in a familiar place and surrounded by friends in contrast to a situation where the victim is alone in an unfamiliar place. A context management system can provide such a support for this kind of applications.

The user's context is valuable information in case of emergency because it can include the user's position and location and also provide additional valuable information like the familiarity level with the current place, the presence of nearby friends and relatives or information about the user medical history and known problems. The context of the user can even include information that may suggest the causes of the emergency if it is feed by temperature or acceleration sensors. The ubiquity of mobile phones and networks provide a particularly rich technological environment to gather such information and enable assistance applications for the health care mass market. Most of these applications can rely on the phone's hardware only and be easily deployed in the majority of the current mobile phones. Therefore, all the conditions for a fast dissemination of these applications are fulfilled.

Mobile phones are small and people take them to everywhere, being common the presence of a mobile phone on every people's pocket (including injured victims). Just by using the cell phone it is possible to infer when the user is moving or visiting a place and compute a familiarity level with the user's current location. This kind of information can be computed on the mobile phone and does not need to use any network services.

Detecting the User Movement

When turned on, a GSM phone is linked to a cell - the active cell - which is selected among the cells available in a certain place. The handset movement can not be detected just by analysing the changes in the cell-id because the handset changes from a cell to another when fluctuation occurs in the radio signal level, when it becomes weaker or because the user moves to another place. Thus, even if a terminal stays for a long period in a single place it may change several times the active cell. While remaining in the same place, sometimes a handset stays for hours in one cell while in other occasions it stays only some seconds or minutes in each of the available cells.

By analysing the changes of the active cell during a period of time it is possible to detect the movements. When the terminal is stopped in a certain place it will change between the set of cells available on that place. When the terminal moves to a new place, new cells will become available and will be used. Thus, when the user is moving we observe the use of different cells and faster variations in the active cell.

Computing a Mobility Distance and a Mobility Index makes it possible to detect the user movement (Meneses, 2006). Considering that a record has the identification of a cell being used in a certain moment and that instant timestamp, the Mobility Distance measures the distance between two records. If the user in both moments is in the same cell then the distance is zero. If not, the distance is the inverse of the time spent on each cell. For a list of records, the Mobility Index gives the sum of the mobility distance between each record and all the previous ones. Thus, the Mobility Index allows to estimate the user movement, computing the index from the current time instant back to a certain amount of time back.

CREATING A PERSONAL SPACE MODEL

Considering always the last cells used by a mobile phone it is possible to find out if the user is moving or not, computing the Mobility Index of the records collected during the last minutes (the used cells). When the user is not moving it is possible to characterize the place based on the set of cells used during that time. The place is characterized by the set of cells used and by the percentage of time spent on each cell. The characterization allows create "an image" of the GSM network in that place: we call it a fingerprint.

If the user visits the same place several times then a fingerprints is created in each visit to that place. Several visits to a place result in several fingerprints, which are not necessarily equal because the user' handset spends different amounts of time on each of the available cells (the percentage of time spent on each cell is different). Although different, the fingerprints have some similarity because they were created on the same place served by the same subset of cells.

By clustering similar fingerprints it is possible to group fingerprints, creating a cluster for each place. A cluster is created by the union of fingerprints (that are created based on the cellID) and represents a place visited by a user. To measure the similarity between fingerprints and clusters two functions are used. The first function calculates the percentage of cells in a fingerprint that are also member of a cluster. This function ignores the cells of the fingerprint with less than 1% of time because so small amount of time is not representative of a place. The second function calculates the absolute difference between the percentage of time spent in that cell in each fingerprint (or in a fingerprint and a cluster).

Based on the total distance the system can join a fingerprint to a cluster or create a new one. A new clustering algorithm was created to deal with this data. The new clustering algorithm deal with symbolic data (the fingerprints), supports an endless number of fingerprints and can be applied as the data becomes available. The clustering process allows to create clusters that are continuous changing as new data (new fingerprints) are generated by the user movement.

Inferring the Familiarity of a User with a Place

A cluster contains the same basic information that a fingerprint has. It allows to know which cells exist in the place represented by the cluster and the exact moment (timestamp) the user arrived and leaved the place. Using timestamp data it is possible to know the total amount of time spent in a cluster (place) and the time elapsed since the last visit to that place. Based on the total amount of time spent in a place it is possible to estimate how well a user knows that place – the places best know are the places where a person spends more time. The Knowledge Index represents the knowledge the user has about a place based on the total time spent in it.

Places change as time goes by, with the construction of new buildings, new roads, etc. If a person does not visit a place for a long period then when he/she goes back to that place the changes will be noticed and the person will not feel so familiar with the place. Based on the time elapsed since the last time the user visited a place it is possible to calculate a Forget Index. Combining the Forget Index and Knowledge Index it is possible to obtain a Familiarity Index.

The Familiarity Index expresses the familiarity with the current place and can be very useful to a number of applications. It allows applications to adapt themselves according to the familiarity of the user. For example, in a very familiar place a user will not need help from a GPS guidance (navigation) application – the user knowledge should be enough to know which direction take to go to another place. On the opposite situation, in a completely unfamiliar place, the familiarity index can be useful to trigger an application that guides a user based on GPS coordinates, or an application that provides information about local attractions or about where to get a hotel or a restaurant in the surrounding area. An injured people, in a familiar place, will fell more comfortable and eventually more capable to request help and provide information about his location or get help from a relative. In contrast, an injured people in an unfamiliar place with the anxiety of get medical help will probably fell lost and be much less capable to provide his/her location or other information describing the current situation.

Results

The technology described in the previous section was tested by three different users, clients of two different GSM networks, during several consecutive weeks. The users kept their normal life and manually registered their activities in a diary. The computed results were them compared with the user's diary (ground truth) to access the quality of the results achieved.

The system was tested considering the cells used by the phone during the last 10 minutes, considering the user was immobile when the Mobility Index was less than 6. Results show that the user movements were well detected in most of the occasions. Table 1 summarizes the results achieved considering all the visits made by the users to the different places that took at least twenty minutes.

Between 78% and 90% of the visits made to the several places were correctly detected. The amount of errors is small and a detailed analysis of the data show that those errors occur in very specific situations or places. False positives occur when the user is moving and the system classifies the user as visiting a place while clustering errors represent visits that were correctly detected but the clustering process joined the fingerprint to a cluster that represents other place. Generally the results are very good, considering that two of the users live and work inside cities and visited places very near. If we consider also the visits that takes less than twenty minutes the results range from 70% of visits correctly detected to user B to 86% to user A.

The main problem with the proposed solution are the places visited for very short period of times that sometimes are not detected and places that are very near each other that not always are distinguished. However, even some of the places geographically near and places visited for short periods of time were detected and correctly clustered.

An analysis of data allows explain most of the errors detected. User A lives inside a big city and works in another city located 35 km away from his house. Everyday, he goes to work by car, crossing a rural area, travelling in a narrow and sinuous road. Analysing the user data we see that false positives are the most common error in user A data and always occur when the user is going to

Table 1. Results achieved by the three users

	User A		User B		User C	
Visits to different places	59		123		147	
Visits correctly detected	53	(89,8%)	95	(77,2%)	121	(82,3%)
Clustering errors	3	(5,1%)	12	(9,8%)	4	(2,7%)
Partially well detected	0	(0%)	11	(8,9%)	9	(6,1%)
Faults	3	(5,1%)	5	(4,1%)	13	(8,9%)
False Positives	31		10		11	

work. Because he drives in relative slow speed in a rural area (where the number of GSM cells is small and each one covers a wide area) then he uses the same set of cells for several minutes. The use of the same set of cells makes the mobility index to decrease below the threshold that defines the boundary between considering the user moving or not moving. Thus, the system considers the user is visiting a place when, in fact, he is travelling. Although this is a false positive, it is not a completely mistake because in fact the user knows the area has he travels by that road everyday.

Many of false positive registered for the others users can also be explained by analysing data detailed. For example, false positives occur when user B is travelling with the family and when user C travels in a natural park, in an inhabited area. User B diary shows that the users travelled, by car, near the sea. Considering the distance and the amount of time the trip took, it is possible to conclude that the user travelled very slowly and/or stopped to visit a place. User B does not remember exactly what he has done on that afternoon but admitted that stopped visiting some beaches in the shore. User C travelling in a natural park with narrow and twisted roads experimented the some problem that occurred to user A: he drove even more slowly and for a long time inside the same cell (being an inhabited area it has only one or two GMS cells). Thus, by an analysing data it is possible to explain many of the errors.

In (Maitland, 2006) it is presented a solution to detect the users' daily activity, through the use of am unmodified mobile phone. The solution is based on an application that works detecting patterns in signal strength fluctuation and changes in the active GSM cell to infer whether the user is sitting still, walking or travelling by car.

Although not completely accurate in the inference of the user' activity and in the detection of the amount of exercises done by the users, the study shows that people are willing to accept applications that do not produce 100% accurate results. Running on a mobile phone (which is a device originally developed for communications proposes) the application has the merit to also encouraged people to do more exercise which brings recognized benefits for people health. Even having knowledge of the accuracy of the application results people felt motivated to do exercise in order to be healthier (and achieve higher values in the application). In (Tsai, 2006) it is presented another solution based on mobile phone which allows users to self-monitor caloric balance in real time.

There is a big set of new technologies can be applied to help patients and emergency personnel. However, apply technologies to complex, stressed and emergency situations imply some constrains. Data networks can fail, wireless systems are even more unreliable and in stressful situation the interfaces and systems must be simple and reliable. Medical and emergency equipment does no comply with unreliable, inaccurate and not easy to use systems.

Location based on GSM cell-ID is not the most accurate positioning system but still produces very valuable data for the user context, which can be useful in many circumstances, including emergency situations. We do not propose a medical system based on cell-id but the use of position data to improve the context and enable a new set of applications that can use the familiarity level.

All information related to an ill person is important to emergency services and, sometimes, as the result of panic or stressful situation people are not capable of provide detailed and complete information. The presented solution can be valuable for users in many circumstances, including injured people, victims of accidents or sudden illness.

A simple alarm application that is executed in a mobile phone by pressing a button can trigger medical assistance providing valuable information about the user context to rescuers. By pressing the button, the user activates an application that collects information about the current situation/

environment and sends an alert message based on the detected situation. The alert message can transmit information like the location of the user (available in the user context), the user familiarity with the surrounding environment, the identification of the user (which could allow access to his medical records by the emergency services) or even some dimensions of the user context that express the user medical history.

CONCLUSION

The existent technology allows create a new class of applications that explores the rich technological environment that today exist almost everywhere. The pervasive and ubiquitous technologies present everywhere and the use of inference techniques enables the creation of innovative applications in the healthcare domain. The solution presented in the previous section is just an example of these inference techniques. Although it has not been tested in any specific case in the healthcare domain, we foresee that the application of the proposed system can bring important benefits to this domain.

REFERENCES

LaMarca, A., Chawathe, Y., Consolvo, S., Hightower, J., Smith, I., Scott, J., et al. (2005). *Place Lab: Device Positioning Using Radio Beacons in the Wild*. Paper presented at the Third International Conference Pervasive Computing (PERVASIVE 2005), Munich, Germany.

Maitland, J., Sherwood, S., Barkhuus, L., Anderson, I., Hall, M., Brown, B., Chalmers, M. & Muller, H. (2006). *Increasing the Awareness of Daily Activity Levels with Pervasive Computing.* Paper presented at 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Meneses, F., & Moreira, A. (2004). *A Flexible location-context representation*. Paper presented at the The 15th IEEE international Symposium on Personal, Indoor And Mobile Radio Communications (PIMRC2004), Barcelona, Espanha.

Meneses, F., & Moreira, A. (2006). *Using GSM CellID Positioning for Place Discovering*. Paper presented at the First Workshop on Location Based Services for Health Care (LOCARE'06) at the 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Moreira, A., & Santos, M. (2005). *Enhancing a user context by real-time clustering mobile trajectories*. Paper presented at the International Conference on Information Technology: coding and computing – ITCC 2005, Las Vegas, NV, USA.

Tsai, C., Lee, G., Raab, F., Norman, G., Sohn, T., Griswold , W., & Patrick, K. (2006). *Usability and Feasibility of PmEB: A Mobile Phone Application for Monitoring Real Time Caloric Balance*. Paper presented at 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Want, R., Hopper, A., Falcão, V., & Gibbons, J. (1992). The Active Badge Location System. *ACM Transactions on Information Systems, 10*, 91-102.

Ward, A., Jones, A., & Hopper, A. (1997). A New Location Technique for the Active Office. *IEEE Personal Communications, 4*, 42-47.

Weiser, M. (1991). The computer for the 21st century. *Scientific American, 265*(3), 94-104.